CALIFORNIA DIVISION OF HIGHWAYS
BRIDGE DEPARTMENT COMPUTER SERVICE

TUNNEL ARCH ANALYSIS

INSTRUCTIONS FOR USERS

This service will calculate stresses in a symmetrical, reinforced concrete arch section subjected to a series of pressure loadings. Supports may be either fully fixed or fully pinned. Analysis follows the precedure outlined in the "Portland Cement Association Publication ST53."

DATA PREPARATION (on Forms H-BD D 74, 75 and 76)

Identification: District, Group, Batch and accounting data are standard. See General Instructions for Users, Memo to Designers 20-1. A Problem number may be added if useful. Identification must be identical on all sheets for a given problem.

Loadings:

FIX or PIN	ARCH UNIT WT.	C. G. REINF. TO EDGE CONC. (.01 in)	
		INTRADOS	EXTRADOS
41	44	47	51

S/C 1515

1. FIX or PIN - Support Fixity. Write in appropriate word.

2. ARCH UNIT WT. - Unit weight of arch material (lb/cu.ft.). It will be neglected if left blank.

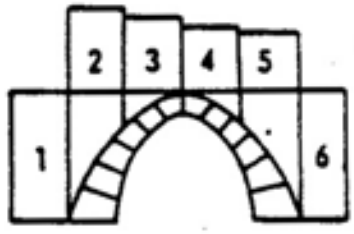
3. C. G. REINF. TO EDGE CONC. - Distance from face (intrados or extrados) to C. G. of reinforcement for that face (in.).

(Formerly Memo to Designers 20-26)

LOAD NO	LOADING PRESSURES (.01 K/sq. FT.)					
9	1 (11)	2 (16)	3 (21)	4 (26)	5 (31)	6 (36–40)
1						
2						
3						
4						

4. LOAD NOS. must be consecutive starting with one. Input sheets are prenumbered for convenience. A maximum of 15 loadings may be submitted with any one problem.

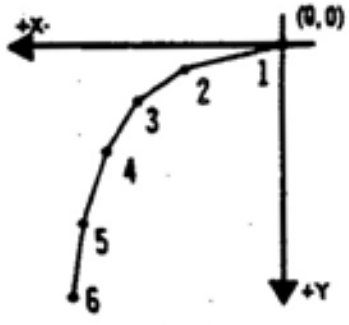
5. LOADING PRESSURES, numbered 1 through 6, correspond to the Loading Pressure Key. All pressures are assumed to act toward the arch section. A loading of all zero pressures (entered as zeros, not left blank) yields an analysis of dead loads. Pressures are in kips/sq.ft.



LOADING PRESSURE KEY

Coordinates:

POINT NO. (1–2)	X (.01 ft.) (11–16)	Y (.01 ft.) (17–22)
1	0.0.0	0.0.0
2		
3		



AXIS COORDINATES

1. POINT NOS. must be consecutive starting with one at the crown. Input sheets are pre-numbered for convenience. A maximum of 51 points may be submitted. The points described form segmental limits for the left half-section.

2. X coordinates are in feet. Point one must be zero. Describe only the left half of section. All coordinates must be positive from the crown.

3. Y coordinates are in feet. Point one must be zero. Describe only the left half of section. All coordinates must be positive downward from the crown.

Arch Description:

SEG NO. 9	SEGMENT THICKNESS (.01 ft.) 11	REINF. (.01 sq. in./ft.)	
		INTRADOS 17	EXTRADOS 18 24
1			
2			
3			
4			

1. SEG. NOS. must be consecutive from the crown, starting with segment one. Input sheets are pre-numbered for convenience. A maximum of 50 segments may be submitted.

2. SEGMENT THICKNESS is in feet, measured normal to the axis at C. G. of each segment.

3. REINF., given separately for each segment, is in sq. in./ft. at each fact (intrados and extrados).

RESULTS

Results consist of four types of printed pages as follows:

1. ARCH DIMENSIONS include coordinates, thicknesses and reinforcement describing the arch section. Coordinates are referenced to the computed neutral point.

1A ARCH PROPERTIES includes for each segment the following values:

N = Segment number

A = Segment length/(segment thickness)^3

AY = (A) (distance from neutral point to segment center)

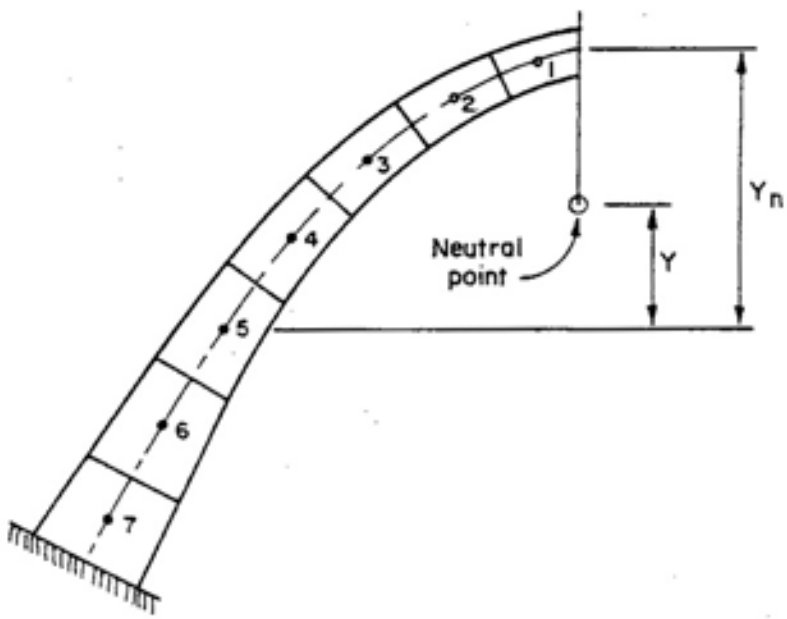
The following totals are also provided:

SUMAY^2 = AY^2

SUMAX^2 = AX^2

SUMA = A

YBAR = $Y_{np} = \dfrac{A(Y_n)}{A}$ (Yn) = distance from original axis to segment center in y direction



2. ARCH FORCES AND STRESSES are shown on one page for each load described. Contents are the forces and stresses in each segment. End condition is also given on this sheet.

Concrete sections are considered cracked whenever P/A - MC/I of transformed areas is negative.

Maximum reinforcement stresses are either:

(a) 10 times the straight line concrete stress at the level of the tensile reinforcement; or,

(b) 19 times concrete stress at the level of the compression reinforcement.

The signs of all stresses are: Minus = compression
Plus = tension

Minus thrust indicates compression and minus moment indicates the extrados is in tension. A tensile or positive thrust will yield zero concrete stress and reinforcement stress of 999999.9.

Input loadings 1 through 6 are shown to permit a check on input used.

2A OPTIONAL RESULTS includes for each segment the following values:

Cantilever Moments (left & right)

Horizontal and Vertical Forces (left & right)

The following totals are also printed:

MO = Neutral Point Moment

HO = Neutral Point Horizontal Forces

VO = Neutral Point Vertical Forces

SMA = (Cantilever segment moment) (A)

SMAY = (Cantilever segment moment) (A)(Y)

MISCELLANEOUS COMMENTS AND HINTS

The coordinate description of points along a line establishes the ends of the segments used for analysis.

Greater accuracy is obtained by use of a large number of segments.

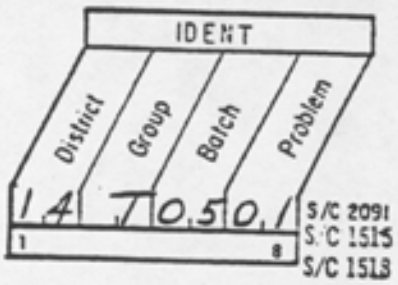
Geometric limitations prohibit the use of more than 2 successive points with identical Y coordinates. This case can be approximated, however, by varying the Y coordinate by .01 ft. from point to point.

The designer should make a careful check of output coordinates to be assured the program has analyzed the desired section.

SAMPLE PROBLEM

On the following pages is an example problem showing data and results.

EXAMPLE PROBLEM - COMPOSITE OF 3 PAGE INPUT



TUNNEL ARCH ANALYSIS

LOADINGS

FORTRAN IV NAME Joe Jones PHONE 3333

LOADINGS PAGE

FIX or PIN	ARCH UNIT WT.	C. G. REINF. TO EDGE CONC. (.01 in)	
		INTRADOS	EXTRADOS
F I X	1 5 0	2 5 0	2 5 0
41	44	47	51

S/C 1515

LOAD NO	LOADING PRESSURES (.01 K/sq. Ft.)					
	1	2	3	4	5	6
9	11 16	21	26	31	36 40	
1	3.0 0	1.0 0	1.0 0	1.0 0	1.0 0	3.0 0
2						

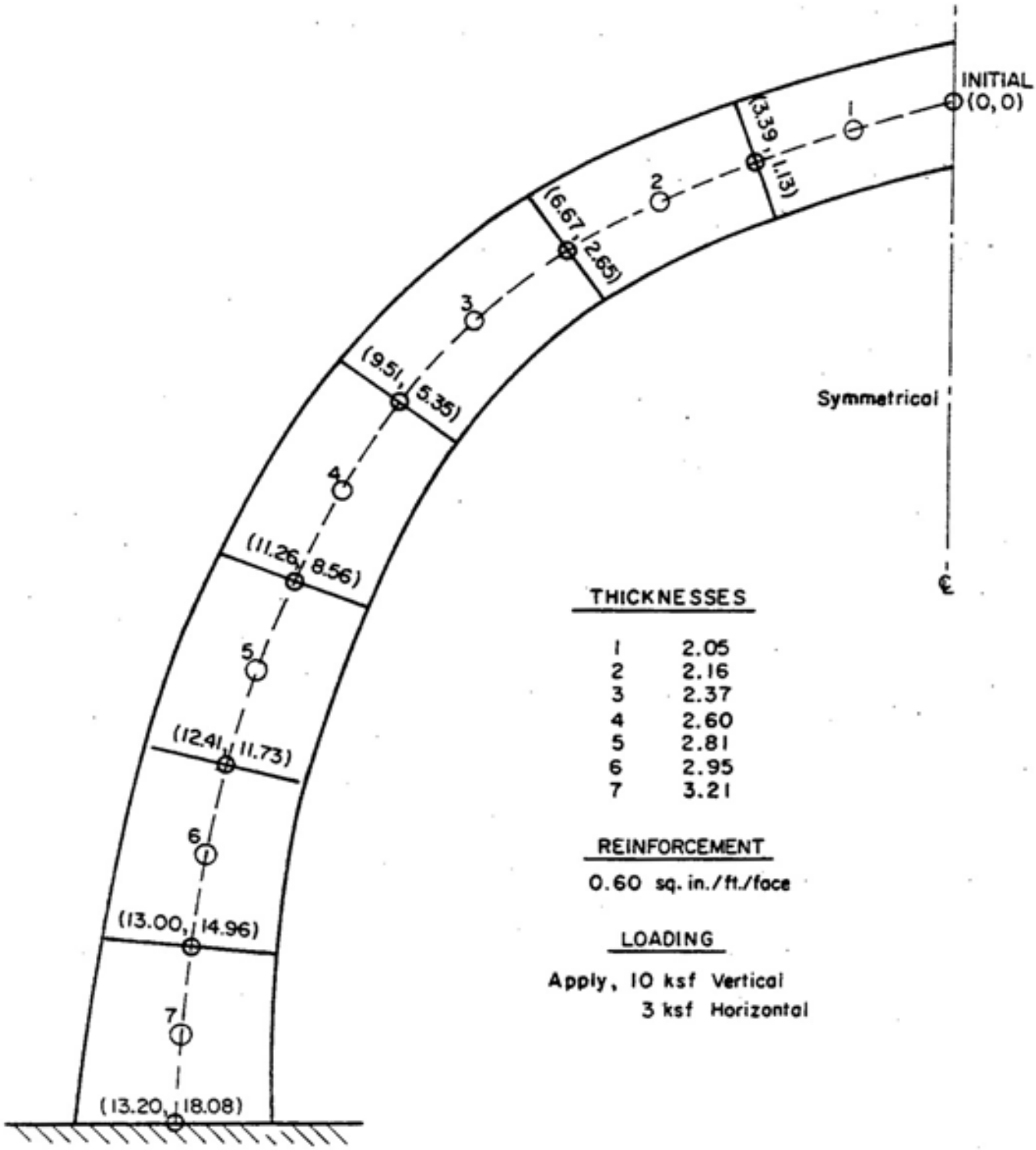
AXIS COORDINATES PAGE

POINT NO.	X (.01 ft.)	Y (.01 ft.)
9	11 17	22
1	0 0 0	0 0 0
2	3 3 9	1 1 3
3	6 6 7	2 6 5
4	9 5 1	5 3 5
5	1 1 2 6	8 5 6
6	1 2 4 1	1 1 7 3
7	1 3 0 0	1 4 9 6
8	1 3 2 0	1 8 0 8

ARCH DESCRIPTION PAGE

SEG NO.	SEGMENT THICKNESS (.01 ft.)	REINF. (.01 sq. in./ft.)	
		INTRADOS	EXTRADOS
9	21	17	25 24
1	2 0 5	0 6 0	0 6 0
2	2 1 6	↓	↓
3	2 3 7	↓	↓
4	2 6 0	↓	↓
5	2 8 1	↓	↓
6	2 9 5	↓	↓
7	3 2 1	↓	↓
8			

EXAMPLE PROBLEM



THICKNESSES

1	2.05
2	2.16
3	2.37
4	2.60
5	2.81
6	2.95
7	3.21

REINFORCEMENT

0.60 sq. in./ft./face

LOADING

Apply, 10 ksf Vertical
3 ksf Horizontal

EXAMPLE PROBLEM - OUTPUT COMPOSITE

14T 0501 TUNNEL ARCH ANALYSIS BOE-008. JUL. 29. 1971 ARCH DIMENSIONS PAGE 01

POINT	EXTRADOS COORDS X	EXTRADOS COORDS Y	AXIS COORDS X	AXIS COORDS Y (0.0) AT NEUTRAL PT.	SEGMENT	SEG CENTER COORDS X	SEG CENTER COORDS Y	SEGMENT THICKNESS	REINF.(IN-2) INT	REINF.(IN-2) EXT
1	0.0	6.14	0.0	5.06	1	-1.69	4.49	2.05	0.60	0.60
2	-2.02	5.47	-3.39	3.93	2	-5.03	3.17	2.16	0.60	0.60
3	-5.48	4.15	-6.67	2.41	3	-8.09	1.06	2.37	0.60	0.60
4	-8.91	1.92	-9.51	-0.29	4	-10.38	-1.90	2.60	0.60	0.60
5	-11.53	-1.28	-11.26	-3.50	5	-11.83	-5.09	2.81	0.60	0.60
6	-13.16	-4.61	-12.41	-6.67	6	-12.70	-8.29	2.95	0.60	0.60
7	-14.16	-8.02	-13.00	-9.90	7	-13.10	-11.46	3.21	0.60	0.60
8	-14.70	-11.36	-13.20	-13.02						

14T 0501 TUNNEL ARCH ANALYSIS BOE-008. JUL. 29. 1971 ARCH PROPERTIES PAGE 1A

SUMAY2 = 38.1455 SUMA = 1.4563
SUMAX2 = 110.1203 YBAR = 5.06

N	A	AY
1	0.4148	1.8635
2	0.3587	1.1363
3	0.2944	0.3114
4	0.2080	-0.3947
5	0.1520	-0.7732
6	0.1279	-1.0599
7	0.0945	-1.0834

14T 0501 TUNNEL ARCH ANALYSIS BOE-008. JUL. 29. 1971 ARCH FORCES AND STRESSES PAGE 2

LOADING NO. 1 3.00 1.00 1.00 1.00 1.00 3.00 (K/SQ.FT.) END CONDITION = FIX

SEG	FORCES (K AND FT) LEFT MOMENT	LEFT THRUST	LEFT SHEAR	RIGHT MOMENT	RIGHT THRUST	RIGHT SHEAR	SEG	AXIAL STRESSES (PSI) LEFT CONCRETE	LEFT REINF.	RIGHT CONCRETE	RIGHT REINF.	SEG
1	-22.22	-31.47	7.20	-22.22	-31.47	7.20	1	-347.1	-6497.1	-347.1	-6457.1	1
2	-0.95	-28.52	5.47	-0.95	-28.52	5.47	2	-92.9	-1737.6	-92.9	-1737.6	2
3	18.38	-23.33	6.65	18.38	-23.33	6.65	3	-215.7	-4047.4	-215.7	-4047.4	3
4	31.47	-18.68	3.38	31.47	-18.68	3.38	4	-356.5	9012.6	-356.5	9012.6	4
5	24.74	-17.04	-4.15	24.74	-17.04	-4.15	5	-253.0	-4720.6	-253.0	-4720.6	5
6	-5.50	-17.78	-11.72	-5.50	-17.78	-11.72	6	-63.2	-1138.5	-63.2	-1138.5	6
7	-57.69	-20.27	-19.68	-57.69	-20.27	-19.68	7	-536.2	17889.9	-536.2	17989.5	7

14T 0501 TUNNEL ARCH ANALYSIS BOE-008. JUL. 29. 1971 OPTIONAL RESULTS PAGE 2A

SMA = -446.35 MO = 135.235
SMAY = 2608.17 HO = -14.151
SMAX = 0.0 VO = 0.0

N	CANTILEVER MOMENTS LEFT	CANTILEVER MOMENTS RIGHT	HORIZONTAL AND VERTICAL FORCES H L	V L	H R	V R
1	-4.03	-4.03	32.13	-3.12	32.13	-3.12
2	-28.01	-28.01	28.18	-7.03	28.18	-7.03
3	-80.73	-80.73	21.49	-11.26	21.49	-11.26
4	-168.56	-168.56	11.91	-14.78	11.91	-14.78
5	-284.23	-284.23	1.91	-17.44	1.91	-17.44
6	-423.75	-423.75	-8.33	-19.60	-8.33	-19.60
7	-584.38	-584.38	-18.34	-21.48	-18.34	-21.48

BATCH CHARGE UNITS= 17 APPROXIMATE MACHINE TIME 0.510 SECS APPROXIMATE MACHINE CHARGE $ 2.40